Spring Ligament Instability

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KEYWORDS

- Spring ligament • Calcaneonavicular ligament • Adult acquired flatfoot deformity • Pes planus • Posterior tibial tendon insufficiency

KEY POINTS

- The spring ligament complex plays a fundamental role in the static stability of the talonavicular joint and the medial longitudinal arch.
- Isolated injury or secondary failure in the context of posterior tibial tendon insufficiency has been related to flatfoot deformity.
- Spring ligament repair and augmentation or reconstruction techniques focus on deformity correction and restoring the medial arch and have been progressively included in the treatment of flexible flatfoot deformity treatment algorithms.
- Restoring normal function of the spring ligament complex has been associated with a decrease in the need for nonanatomic procedures, such as lateral column lengthening and hindfoot fusions.

INTRODUCTION

The complexity of the pathologic process that leads to flatfoot deformity has been only partially understood. The crucial role of spring ligament complex (SLC), however, within this process has recently evolved. Several reasons can explain this situation, which can be summarized in an improvement in anatomic knowledge and

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understanding of the close SLC to deltoid complex relationship and by outstanding advances in biomechanics concepts.

These reasons have led to an optimization of flatfoot treatment strategies. In addition to bony realignment, these treatment strategies focus on a renewed interest in SLC and medial soft tissue reconstruction to obtain an adequate correction of the talonavicular deformity and restoration of the medial longitudinal arch.

ANATOMY

The SLC is a group of ligaments that connect the sustentaculum tali of the calcaneus and the navicular bone. The main function of the SLC is to support the head of the talus, an important part of the articular surface of the talocalcaneonavicular joint, commonly referred to as acetabulum or coxa pedis.[1] The dorsal portion of the ligament is covered by fibrocartilage and articulates through a small triangular surface located at the medial side of the head of the talus.[2]

The SLC is formed by 2 distinct ligamentous bands: the superomedial calcaneonavicular (SMCN) ligament and the inferomedial calcaneonavicular (ICN) ligament (**Fig. 1**). Due to the intrinsic difficulty in dissecting this area, however, the

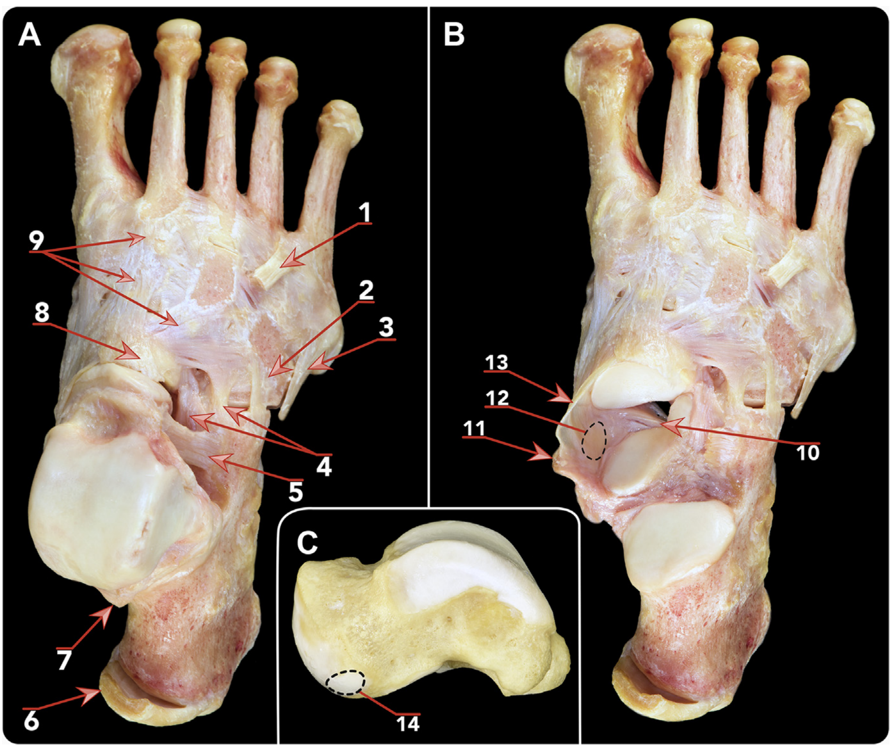

Fig. 1. Osteoarticular dissection of the SLC. (*A*) Superior view of the foot. (*B*) Superior view of the foot with the talus removed. (*C*) Medial view of a right talus. 1, Peroneus tertius tendon. 2, Dorsolateral calcaneocuboid ligament. 3, Peroneus brevis tendon. 4, Bifurcate ligament (calcaneonavicular and calcaneocuboid components). 5, Cervical ligament. 6, Calcaneal tendon. 7, Posterolateral talar tubercle. 8, Dorsal talonavicular ligament (cut). 9, Dorsal tarsal ligaments. 10, Inferior calcaneonavicular ligament. 11, Tibialis posterior tendon. 12, Fibrocartilaginous area of the SMCN ligament. 13, SMCN ligament. 14, Articular surface of the talus for the SMCN ligament.

fibrocartilaginous nature of the dorsal part of the ligaments, and the indivisibility of its distinct components, different descriptions are available in the literature.[3–6] These include 1 study describing a third additional component or midplantar oblique (MPO) ligament as a distinct part of the SLC.[7] Other cadaveric studies include the tibiospring component of the medial collateral ligament of the ankle (deltoid ligament) as part of the SLC, because this fascicle is one of the origins of the SMCN ligament, highlighting the intimate functional relationship between both complexes.[6,8]

The SMCN ligament is a quadrangular structure originating from the anterior and medial margins of the sustentaculum tali and at the anterior margin of the anterior articular surface of the calcaneus. From these points, it directs anteriorly to insert at the margin of the posterior articular surface of the navicular, specifically at the dorsal, medial, and plantar margins of its medial third. The medial portion of this ligament is in close relation with the posterior tibialis tendon (PTT), whereas its lateral portion articulates with the head of the talus.

The ICN ligament is a trapezoidal ligament that holds the inferior part of the talar head (**Fig. 2**). It originates from the coronoid fossa of the calcaneus, which is a small fossa on the sustentaculum tali, between the anterior and middle calcaneal articular surfaces. From this point, it directs medially to insert on the plantar aspect of the navicular, where it is in continuity with the SMCN ligament (**Fig. 3**). A medial and a lateral fascicle can be differentiated in this ligament.

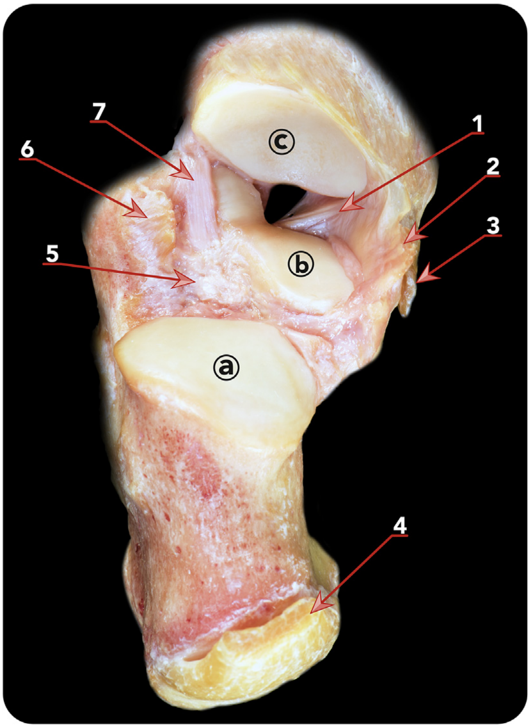

Fig. 2. Superior view of the talocalcaneonavicular joint (talus has been removed) and the SLC. a, Posterior subtalar articular surface of the calcaneus. b, Anterior subtalar articular surface of the calcaneus. c, Posterior articular surface of the navicular. 1, Inferior calcaneonavicular ligament. 2, SMCN ligament. 3, Tibialis posterior tendon. 4, Calcaneal tendon. 5, Interosseous talocalcaneal ligament (cut). 6, Cervical ligament (cut). 7, Calcaneonavicular component of the bifurcate ligament.

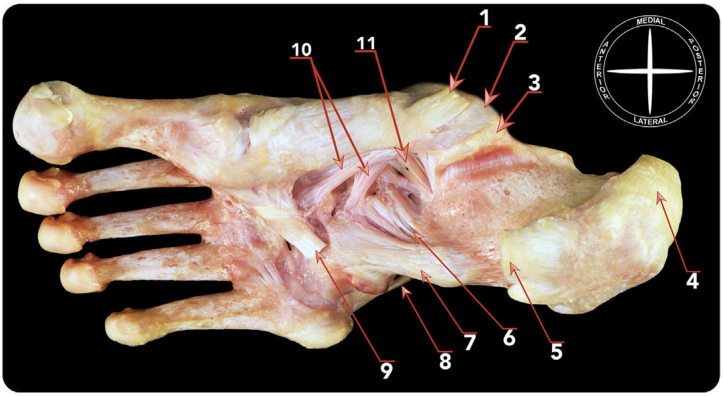

Fig. 3. Plantar view of an osteoarticular dissection of the SLC. 1, Tibialis posterior tendon. 2, SMCN ligament. 3, Sustentaculum tali. 4, Calcaneal tendon. 5, Plantar aponeurosis. 6, Plantar calcaneocuboid ligament. 7. Long plantar ligament. 8. Peroneus brevis tendon. 9, PL tendon. 10, Expansions of tibialis posterior tendon. 11. Inferior calcaneonavicular ligament.

BIOMECHANICS

The acetabulum pedis is conformed by the SLC, the anterior and middle facets of the calcaneus, and the proximal portion of the navicular. This structure provides static stability to the talar head and hence to the talonavicular joint. Moreover, is believed to provide medial longitudinal arch support and to provide kinetic coupling between the hindfoot and the forefoot.[4,9,10]

A cadaveric study by Reeck and collaborators,[11] however, demonstrated that contact forces in the calcaneonavicular ligament are much lower than in other talar articulations. Despite these findings, medial orientation must contribute to stabilize the talar head against medial subluxation.

Histologic reports have shown that the fibrocartilaginous plate of the SMCN ligament is likely formed secondary to repetitive loads it sustains. Likewise, the ICN ligament presents organized longitudinal fibers to resist tensile forces.[4]

CLINICAL PRESENTATION

Isolated Spring Ligament Rupture

Isolated injuries to the SLC in the presence of a normal PTT are uncommon. They usually result in an acquired flatfoot deformity presenting acutely but in some cases manifestations can be insidious and not easily related to a traumatic event. Patients commonly relate eversion injuries of the hindfoot sustained during physical activities progressing to a unilateral planovalgus deformity. Most of these cases are misdiagnosed as medial ankle sprains before developing the characteristic components of the flatfoot deformity: hindfoot valgus, loss of midfoot arch, and forefoot abduction.[12] Even though most of the clinical findings may mimic the classic PTT insufficiency presentation, there are some distinguishing features that can guide the diagnosis.

In a series of 9 cases, Tryfonidis and colleagues[13] described a characteristic clinical sign in patients with SLC insufficiency. Patients retained ability to perform a single leg, tiptoe standing on the affected side with partial restoration of medial arch but with persistent forefoot abduction and heel valgus. In addition, they reported that all their patients presented with tenderness anterior to the medial malleolus in contrast to the posterior-inferior tenderness typically found in PTT rupture and dysfunction. Other investigators have described a more plantar location of the pain, between the sustentaculum tali and the navicular.[9,12]

Differential diagnosis includes acute tears of the superficial deltoid ligament, most commonly at its navicular insertion, but they can also be found at its medial malleolus origin.[14] In the authors' experience, it is not possible to clinically differentiate an acute injury of the SLC from lesions of the deltoid complex. It has been well established that both structures share anatomic components and function as a unit.[6] Although the definitive diagnosis is usually done intraoperatively, the authors suggest the use of MRI to confirm the location of the injury in patients with acute flatfoot deformity.

Role in Acquired Adult Flatfoot Deformity Secondary to Posterior Tibial Tendon Insufficiency

Multiple studies have demonstrated that PTT insufficiency by itself is not capable of producing acquired adult flatfoot deformity (AAFD), even though it is the main dynamic stabilizer of the medial arch of the foot. As part of a progressive pathologic process, dysfunction of the PTT increases stress over the medial structures of the foot and ankle, leading to failure of the SLC and development of talonavicular deformity.[15,16] Tears or attenuation of the SLC, most commonly of the SMCN portion, can be found in more than 70% of the patients with some degree of deformity secondary to PTT insufficiency.[17,18] Diagnosis of this injury has been typically done with MRI evaluation and intraoperative inspection. On the other hand, the role of clinical examination assessing SLC involvement in patients with AAFD secondary to PTT dysfunction is unclear and literature on the matter is scarce.

Pasapula and collaborators[19] described the neutral heel lateral push test to determine SLC integrity. They examined 21 cadaveric specimens to assess the lateral translation of the midfoot when applying a lateral force to the medial midfoot with graduated anterograde and retrograde defunctioning of the PTT and flexor digitorum longus (FDL) tendon. In all specimens, a significant displacement occurred after the SLC was released regardless of the dissection sequence. The investigators concluded that the SLC is the most important ligament preventing lateral translation of the midfoot. They described a clinical test consisting of holding the heel in a neutral position and applying a lateral force to the medial midfoot. A firm endpoint is suggestive of SLC integrity, whereas lateral translation without endpoint suggests injury to the SLC. Clinical validation of this clinical sign, however, is still lacking. In the context of AAFD secondary to PTT insufficiency, clinical determination of SLC injury is currently not reliable.

IMAGING STUDIES

Radiographs

Standard weight-bearing x-ray evaluation continues to be the initial study for evaluation of flatfoot deformity. Despite that radiological findings do not differ from the typical characteristics described for PTT insufficiency, Williams and collaborators[20] reported there was a significant association between an increased Meary talus-first metatarsal angle (over 5°) and SLC injury on MRI.

Ultrasound

Due to the advances in MRI imaging techniques and their dependency on operator experience, ultrasound is usually not included in the first line of study when suspecting an SLC injury. Potential limitations are that it only allows the visualization only of the SMCN component of the SLC with a limited soft tissue contrast. It can be a useful tool, however, for detecting abnormalities in the PTT, frequently associated with SLC pathology.[1,15]

The correct visualization of the SMCN ligament is usually obtained with the probe placed inferior to the medial malleolus, with one end placed over the sustentaculum tali and the other end slightly tilted superiorly over the talar head toward the superomedial aspect of the navicular bone. The normal appearance is a hyperechoic fibrillar structure.

Ultrasound signs of abnormality are loss of normal fibrillar internal structure, marked widening or flattening, a defect or gap, and increased vascularity on Doppler examination.[13]

MRI

MRI is the modality of choice for the evaluation of the SLC by providing an excellent visualization of its tridimensional orientated structure, which allows for assessment of the extent of injury. In addition, MRI is useful to diagnose adjacent abnormalities involving the soft tissue structures of the medial side of the ankle, such as deltoid ligament, flexor retinaculum, and PTT. It also depicts other potential sources of chronic medial ankle pain that are part of the differential diagnosis: tarsal tunnel syndrome, accessory flexor muscles, and subtalar coalition among others.[21]

Spring ligament is often abnormal in patients with acquired flat foot deformity, whether acute or chronic deformity, in isolation or associated with talonavicular dislocation, deltoid ligament, and PTT abnormalities.[21]

SMCN is best visualized in coronal and axial planes (Figs 4A, B). Studies have reported that the normal thickness is between 2 mm and 4 mm.

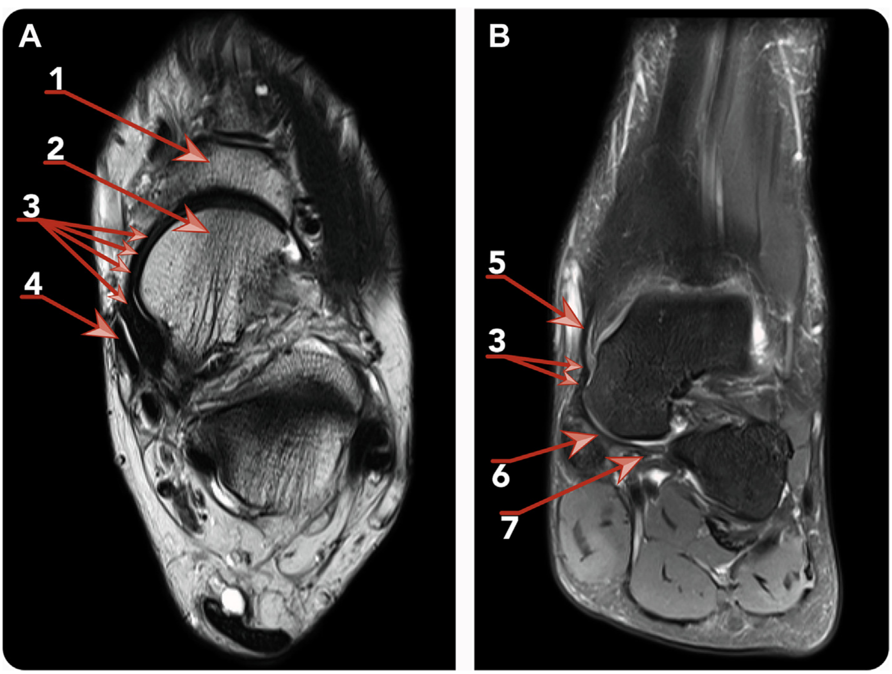

Fig. 4. MRI of normal SMCN ligament. (*A*) Axial T2 weighted. (*B*) Coronal proton density with fat suppression (PD FS) of the ankle. 1, Navicular bone. 2, Talar head. 3, SMCN ligament. 4, Posterior tibial tendon. 5, Tibiospring ligament. 6, MPO band. 7, ICN band.

Different MRI signs of abnormal features of the SMCN have been described.[1,10,22–24] The most common reported signs are increased signal on proton density with fat suppression (PD FS) or T2-weighted sequences, thickening greater than 5 mm, thinning less than 2 mm, and partial or complete discontinuity, including defects in the junction of tibiospring ligament with the SMCN ligament (**Figs. 5–7**).

ICN and MPO portions are best visualized in the axial plane but are also seen in sagittal and coronal images[10] (**Fig. 8**). MPO band is the thinnest portion, with a mean thickness of 2.8 mm (range:1–5 mm). It looks striated in T1-weighted and T2-weighted images with alternating layers of fibers bundles and fat.[22,23]

ICN band is short and thick, separated from the MPO band by fat and the spring ligament recess, and runs slightly oblique to the long axis of the foot. It has intermediate signal in T1-weighted and T2-weighted images and a mean thickness of 4 mm (2–6 mm). Pathology affecting these bands is infrequently reported.[23]

TREATMENT

Management of SLC injuries are immersed in conventional flatfoot deformity treatment strategies, including medializing sliding calcaneal osteotomy, lateral column lengthening, and FDL transfer. All these procedures aim to reduce the stress on the medial structures but none of them manages to reconstitute the plantar arch in a satisfactory way.[16]

Repair or reconstruction of the SLC has usually been reported as an adjunctive procedure in stage IIB flatfoot deformity before progression to later stages and severe collapse of the midfoot and rigidity develops.[17] Furthermore, some investigators have proposed that SLC reconstruction may avoid the need of nonanatomic procedures like lateral column lengthening and even subtalar and midfoot fusions in severe

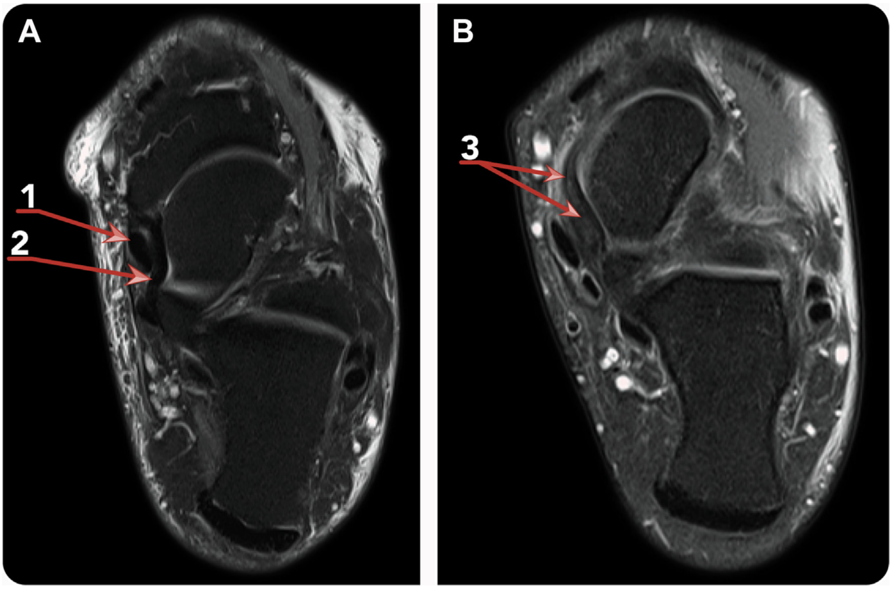

Fig. 5. MRI of SMCN ligament thickening. (*A and B*) Axial PD FS. 1, Posterior tibial tendon. 2, SMCN thickened. 3, SMCN thickened and increased in signal. (*B*) Note the surrounding edema due to chronic stress to the soft tissue.

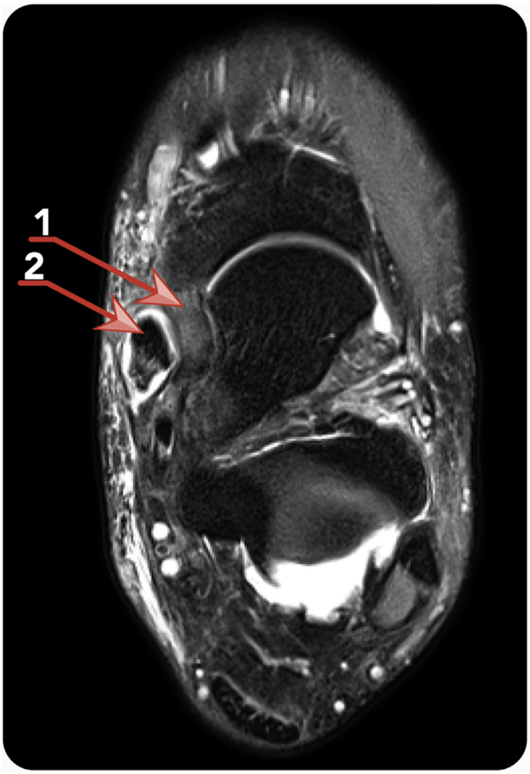

Fig. 6. MRI of SMCN ligament with marked thickening and increased signal. Axial PD FS. 1, SMCN. 2, Posterior tibial tendon with degeneration and tenosynovitis.

deformities.[25] Including SLC repair, however, did not significantly enhance bony correction in a flatfoot cadaveric model under cyclic loading.[26]

The investigators suggest that the presence of SLC injuries are habitual when midfoot abduction (>5° anteroposterior talar—first metatarsal angle and/or >30% talar head uncoverage) and/or talonavicular sag (>5° lateral talar—first metatarsal angle) are present. Surgeons must be prepared to perform a repair or reconstruction of the SLC if confirmed during inspection.

Isolated SL injuries are amenable for repair or reconstruction without adjunctive procedures. Several reports have demonstrated excellent results with isolated procedures after acute tears. Chronic isolated lesions associated with attenuation of the medial structures, however, may require additional procedures in a similar fashion as flatfoot reconstruction, even in the absence of PTT pathology.[27]

Adequate intraoperative visualization of the SLC can be demanding but it is imperative for diagnosis confirmation and for appropriate repair or reconstruction, independent of the surgical technique. Orr and Nunley[27] suggest positioning the ankle and hindfoot in full inversion with plantar retraction of the PTT. This provides excellent visualization of the superomedial portion and most of the middle and inferior portions of the SLC.

Direct Repair

SLC tears are frequently the result of a chronic degenerative process, resulting in an attenuation of the tissue that makes repairing it unpredictable.[5] Macklin Vadell and

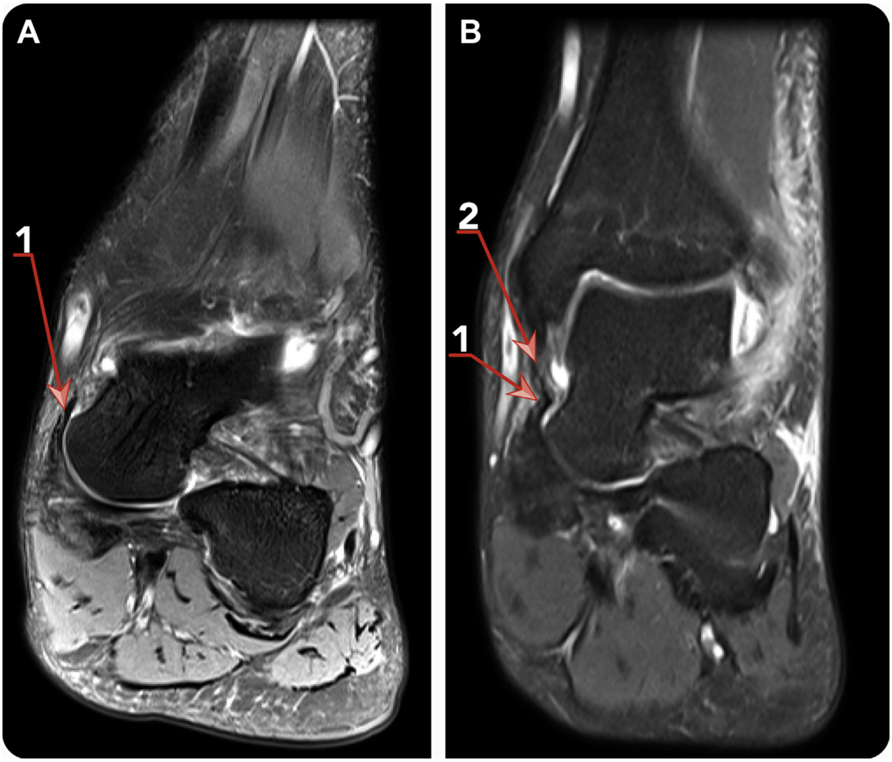

Fig. 7. MRI of Partial rupture of the SMCN ligament. (*A and B*) Coronal PD FS. 1, SMCN. 2, Tibiospring ligament. (*B*) Note also in (*B*) tibiospring ligament rupture, disruption of deep components of deltoid ligament and lateral soft tissue edema.

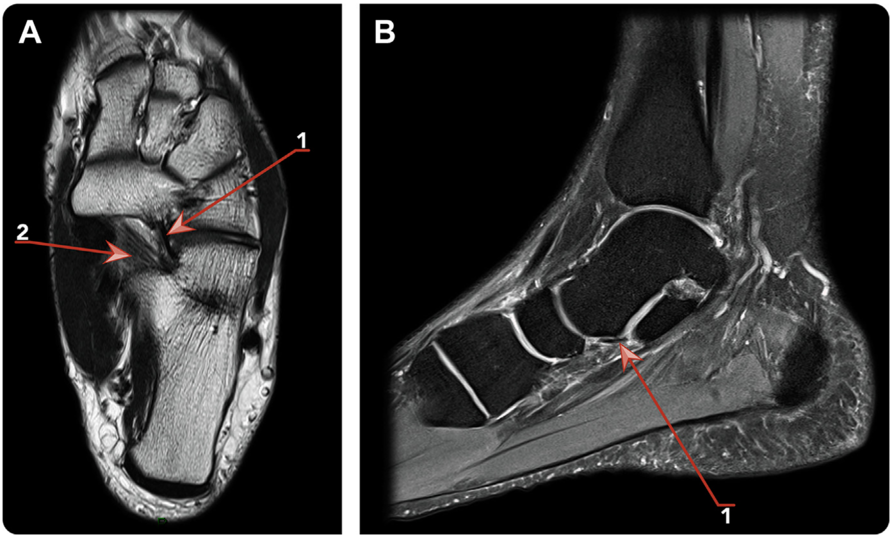

Fig. 8. MRI of Normal ICN and MPO components of the SLC. (*A*) Axial T2-weighted. (*B*) Sagittal PD FS. 1, ICN band. 2, MPO band.

Colleagues, however, recommend resecting the lesions ends and suturing the remaining portions with reabsorbable stiches for lesions smaller than 1 cm. For larger lesions, a Z-shortening tenotomy of the PTT can be added to the procedure, to protect the repair.[9]

Other techniques described for direct repair include advancement and reinsertion through transosseus navicular drill holes, plication of the talonavicular capsule, and re-tensioning in vest-over-pants fashion.[12,28]

Recently, Lui[29] described an endoscopic technique for repairing the superficial deltoid ligament and the SLC. Repair is performed through a PTT endoscopy and/or talonavicular arthroscopy, depending on the compromise of the tibiospring or SMCN ligament. The advantage of this method is limited soft tissue dissection, but caution must be paid to not injuring the medial plantar nerve. Clinical results remain to be reported (**Fig. 9**).

Reconstruction

Strategies oriented to reconstruct the SLC rely on the principle that native tissues are usually degenerated and attenuated and not suitable for repair. Thus, reconstruction with tendon autograft or allograft theoretically could better withstand stress forces across the talonavicular joint and maintain correction of the deformity.

Several options have been described to reconstruct the SLC, mainly on cadaveric studies. Deland and collaborators[30] described a deltoid ligament bone-block graft taken from the medial malleolus that preserved the insertion of superficial portion of the ligament at the sustenculum tali. The bone-block was attached to the navicular after correction of the longitudinal arch with manipulation. This technique was able to partially correct the deformity under radiological examination but was not clinically successful.[16] Thordarson and colleagues,[31] on the other hand, created a flatfoot deformity model on 6 fresh-frozen cadavers and compared the use of peroneus longus (PL), tibialis anterior, and Achilles tendon transfers under cyclical loads. Reconstruction with PL tendon provided significantly greater correction in the sagittal and transverse planes across most loads. The other techniques performed poorly with premature failure and loss of correction at lower loads. Despite its success in the laboratory, this procedure was not applied in the clinical setting.

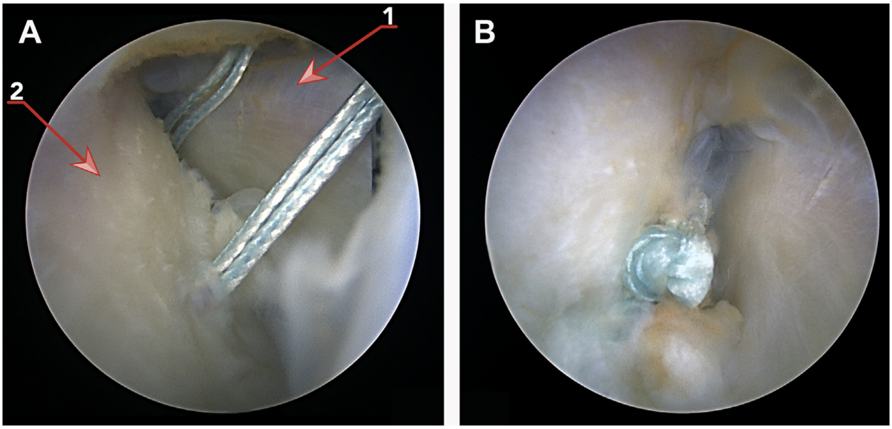

Fig. 9. (*A*) Tibialis posterior tendon (1) endoscopy with assessment of the tibiospring ligament. The SLC corresponds to the medial wall of the tendon sheath (2). If a tear is present, the talar head will be exposed. (*B*) Repair is performed by using a CPR Viper suture passer preloaded with a no. 2 FiberWire suture. (*Courtesy of* Dr Hector Masaragian MD, Buenos Aires, Argentina.)

Choi and colleagues[32] proposed an anatomic approach to SLC reconstruction that also used the PL tendon and compared 3 reconstructive variations to recreate the SLC on a cadaveric flatfoot model: superomedial, plantar, and combined reconstruction techniques. The combined superomedial/plantar passage of the tendon through the calcaneus and navicular was shown more effective than either of the other 2 simple approaches, correcting the talonavicular joint from an abducted to and adducted position and the subtalar joint from an everted to an inverted position. The investigators concluded that the combined PL technique recreates the normal anatomic restraints of the native SLC while successfully correcting the deformity. They express a minor concern on the effects of losing the PL effect as a plantar flexor of the first ray but highlighting the positive effect on the rebalancing of the foot secondary to the elimination of the abducting and eversion forces of the PL.

Williams and collaborators[25] published a clinical series on SLC reconstruction. They reported on 13 patients (14 feet) undergoing flatfoot surgery with SLC reconstruction using a PL tendon transfer for those cases in which lateral column lengthening failed to correct forefoot abduction. Decision to reconstruct the spring ligament was taken intraoperatively after bony procedures using fluoroscopy and simulating weight bearing to assess persistent talonavicular abduction (more than 30°) or talonavicular sag (more than 10°). The PL tendon was harvested proximal to the extensor retinaculum, left attached to the base of the first metatarsal, and retrieved through a medial approach. The graft was then passed from dorsal to plantar through a navicular bone tunnel. Fixation of the proximal end of the graft was done differently according to the characteristics of the talonavicular deformity. If significant plantar sag was found in addition to the abduction deformity, a calcaneal hole was created and used for fixating the graft at this level, thus reducing both components of the deformity (10 patients). In cases of presentation only with abduction deformity, however, a tibial drill hole was made to fixate the graft more proximally (4 patients). The American Orthopedic Foot and Ankle Society (AOFAS) Hindfoot score increased significantly from 43.1 preoperatively to 90.3 postoperatively. All radiological measurements had significant improvement. Eleven patients had excellent satisfaction results and 2 patients reported good results (3 feet). Eversion strength remained normal in all but 1 case.

The fact that patients received different concomitant procedures like FDL transfer, medializing calcaneal osteotomy, or first tarsometatarsal fusion makes it difficult to identify the real effect of the SLC reconstruction. Nevertheless, the outcomes were comparable to other reports, including patients undergoing lateral column lengthening or medializing calcaneal osteotomy with FDL transfer without SLC reconstruction.[33] Moreover, the investigators advocate the use of reconstruction of the SLC complex in the context of severe flatfoot deformity to avoid double arthrodesis or triple arthrodesis of the hindfoot.

Baxter and colleagues[34] compared 3 different reconstruction techniques with PL tendon on a flatfoot model without bony procedures or tendon transfers. The investigators compared an anatomic double bundle technique with 2 nonanatomic reconstructions (talonavicular and tibionavicular configurations). Anatomic reconstruction provided the least amount of correction of the midfoot deformity and had no effect correcting hindfoot valgus. There was a graded effect between deformity correction and proximal fixation of the reconstruction, with the tibionavicular technique providing the most correction of hindfoot valgus, even though it had no interface with the calcaneus. The investigators concluded that reconstructive techniques that included the tibial attachment better corrected midfoot and hindfoot deformity in comparison to anatomic reconstruction and similarly to deltoid complex reconstruction.[35]

Flexor hallucis longus (FHL) tendon autograft reconstruction was described by Lee and Yi on 23 patients.[36] This tendon was selected because of its origin from the deep posterior compartment of the leg, similar to the PTT. The investigators harvested the FHL tendon at the level of the first metatarsophalangeal joint and passed it from plantar to dorsal through the medial cuneiform and then reoriented it in a plantar direction through the navicular and finally passed it from medial to lateral through the sustenculum tali. Clinical outcomes were reported at an average of 8.2 months' follow-up, with an improvement of the AOFAS ankle-hindfoot score from 72.6 preoperatively to 86.4 postoperative. Radiographic parameters were also improved by this reconstruction technique. According to the investigators, this technique reestablishes the static support of the SLC, provides a dynamic midfoot support, and thus eliminates the need for a concomitant FDL transfer.

The use of autologous PTT also has been recently described.[3,37] The rationale behind this alternative approach is to use the diseased PTT that is usually resected during flatfoot reconstruction, and avoid sacrificing a healthy tendon (PL, TA, and FHL). Rysmann and Jeng[37] described a single bundle procedure, consisting of a proximal release of the PTT while maintaining an intact distal attachment. The proximal stump is then passed through a single bone tunnel in the sustenculum tali and tensioned to resemble the SLC. The investigators present results on 3 patients that were reconstructed via this technique in conjunction with medializing calcaneal osteotomy, FDL transfer, and gastrocnemius recession. At 1-year average follow-up, they report excellent radiologic results without evidence of persisting pain over the reconstruction site secondary to leaving the degenerated PTT. The investigators recommend using an alternate reconstruction technique in cases of a PTT that is absent or unusable.

Repair and Augmentation

New alternatives of treatment to complement and reinforce direct repair of the SLC have appeared with development of modern systems for soft tissue augmentation. Tendon harvesting performed during reconstruction can be related to morbidity and loss of strength.[5] Additionally, augmentation techniques may reduce the need of demanding reconstructive techniques and subsequently, the need for tendon harvesting.

Acevedo and Vora[38] described an augmentation technique with FiberTape (Arthrex, Naples, Florida) that replicates both the SMCN and ICN bands of the SLC in association with additional adjunctive bony procedures. The proximal limb (double) is secured at the level of the sustentaculum tali using an interference screw. A single limb is used to replicate the SMCN band by advancing the FiberTape from dorsal to plantar in the medial pole of the navicular. The second limb is then passed from plantar to dorsal, replicating the ICN ligament, in conjunction with the FDL longus tendon transfer. Both FiberTape limbs and the transferred tendon are then secured with another interference screw. The investigators reported the results in 26 patients with only one case presenting radiologic failure. Furthermore, they reported greater correction of the medial arch when using this technique than when performing FDL transfer and medializing osteotomy alone. The advantage of this technique is that it avoids the need of drill multiple tunnels around the sustentaculum tali and potentially decreases the necessity of additional lateral column procedures or subtalar arthroereisis by dramatically improving talar head coverage. Long-term correction of the medial arch using direct repair and augmentation is still to be determined.

Palmanovich and colleagues[39] described a direct repair with nonabsorbable suture followed by reinforcement with FiberTape passed through drilled tunnels in the sustentaculum tali and the navicular, forming a **Fig. 8**. The remaining limbs were anchored to the medial malleolus to reconstruct the anterior fibers of the deltoid ligament. In a subsequent article,[40] the investigators reported the results of their technique in 5 patients with isolated SLC injury. All patients had clinical improvement and were able to perform single heel rise at 1 year follow-up. The AOFAS ankle-hindfoot score also showed improvement from 55.8 before surgery to 97.6 postoperatively during the first year after surgery. No improvement was noted after 1-year follow-up and no clinical recurrence was observed at 5 years' to 10 years' follow-up.[40]

AUTHORS' PREFERRED METHOD OF TREATMENT

The authors propose that isolated injuries or attenuation of the medial soft tissue restraints that produce talonavicular abduction and, in particular, hindfoot valgus should be addressed by direct repair and augmentation not only of the SLC but also the deltoid complex (**Fig. 10**). This concept relies on the SLC and deltoid ligament not only sharing anatomic components but also functioning as a biomechanical unit.[6] Both clinical and biomechanical studies have highlighted the importance of including the deltoid complex in the reconstructive plan, especially in the context of AAFD secondary to PTT insufficiency.[15,25,34,39,40] The authors present a combined augmentation technique that includes acting on both the SLC and deltoid ligament complex. In this setting, Nery and colleagues[41] recently reported satisfactory results on 10 patients operated using this concept. In the AAFD setting, the authors perform this technique in conjunction with lateral column lengthening and/or medializing calcaneal osteotomy with FDL transfer.

Combined Anatomic Spring and Deltoid Ligament Augmentation Associated with Flexor Digitorum Longus Transfer

The patient is placed in the supine position with a thigh tourniquet. If indicated, a lateral column lengthening and/or medializing calcaneal osteotomy are performed

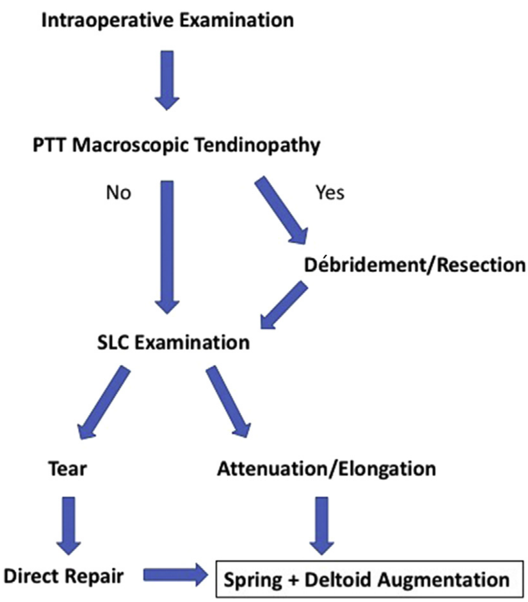

Fig. 10. Author's algorithm of treatment of SLC injuries.

in a conventional manner first. A medial incision is carried out from 2 cm proximal to the tip of the medial malleolus, just behind the posterior border of the tibia and directed toward the navicular tuberosity. After blunt dissection of the subcutaneous tissue, the flexor retinaculum is opened and the PTT is inspected. All macroscopic tendinopathy is resected. There are situations, however, in which part of the navicular insertion can be retained, in particular in those patients with low-quality residual medial ligaments.[37] Careful examination of the SLC and direct repair is performed if any identifiable tear is present. In most cases, global attenuation of the medial tissues is present, so the authors proceed to the combined augmentation procedure (**Fig. 11**A, B).

Dissection of the FDL tendon is then carried out distally where it is just before the knot of Henry. The distal free end of the tendon (1 cm) is prepared using a Krackow technique with FiberLoop suture (Arthrex), and its diameter is measured using a Bio-Tenodesis (Arthrex) guide (**Fig. 11**C).

The authors proceed to locate the sustentaculum tali, where the first blind tunnel is going to be drilled. This tunnel will be shared by the tibiocalcaneal arm of the deltoid ligament and spring ligament internal brace. A 1.35-mm Kirschner (K)-wire is inserted in the sustentaculum tali, angled 15° plantarly and slightly posterior to avoid the subtalar joint. Position can be checked under fluoroscopy prior to drilling with a 3.4-mm cannulated drill.

The next step is to elevate the medial ligament complex from the medial malleolus in a Brostrom fashion, following the osseous contour from medial to lateral and leaving tibial periosteum proximally, for a pants-over-vest repair at the end of the procedure. The tibial blind tunnel will be created in the intercollicular groove using a 3.4-mm drill bit angling proximally and then tapped with the 4.75-mm SwiveLock Tap (Arthrex). Then, a 3.5-mm corkscrew anchor is placed in the anterior colliculus in preparation for retightening of the entire medial ligament complex (**Fig. 12**).

To prepare the talar tunnel, the deltoid ligament is retracted distally to locate the insertion of the deep deltoid ligament in the talus. Talar blind tunnel preparation is performed in the same way than tibial tunnel was prepared. Angulation toward the talar body is necessary to achieve optimal purchase. After preparation is completed, the deltoid ligament is retracted proximally and a stab incision is performed immediately over the talar tunnel position, to maintain the internal brace augmentation superficially to the retightened medial ligament and mark the location of the talar tunnel underneath (**Fig. 13**).

The last tunnel to be prepared is the navicular tunnel. After placing a K-wire in an adequate position in the navicular by leaving at least 1 cm of bone from the medial border, the authors drill with a cannulated 5.0-mm drill from dorsal to plantar. Drill

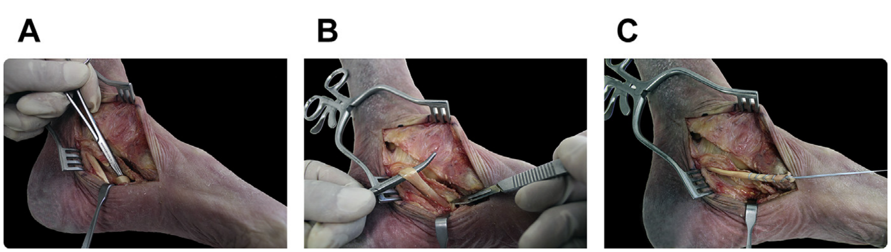

Fig. 11. Dissection of the FDL tendon. (*A*) Identification of the FDL tendon at the plantar aspect of the foot. (*B*) Distal end harvested just before Henry knot. (*C*) 1 cm from the free-end of this tendon is prepared with a Krackow suture.

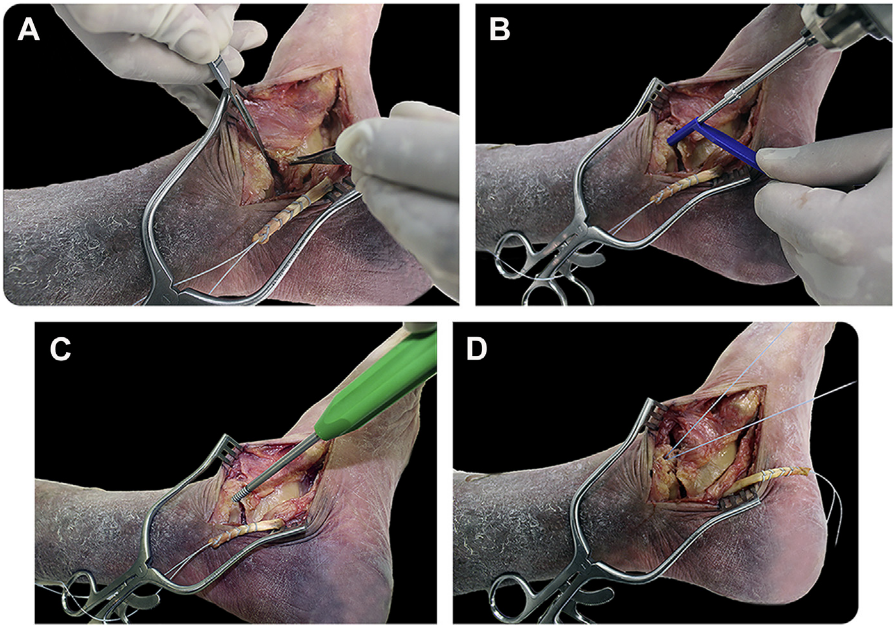

Fig. 12. Medial malleolus tunnel preparation. (*A*) Dissection of the medial ligament complex from the medial malleolus. (*B*) Tibial blind tunnel is placed in the intercollicular groove. (*C*) Tapering of the tibial blind tunnel. (*D*) Insertion of a 3.5-mm anchor at anterior colliculum.

size should be selected considering bone quality and FDL tendon diameter. In cases of adequate bone quality, the authors recommend drilling 0.5 mm over tendon size (Fig. 14).

Once all 4 blind tunnels have been adequately drilled and tapped, the authors perform the medial Brostrom-type retightening, by performing a Mason-Allen stitch using FiberWire (Arthrex) sutures loaded in the 3.5-mm corkscrew anchor. The foot should be maintained in inversion while the knots are being tied (Fig. 15).

After the medial Brostrom has been completed, augmentation with internal brace is performed. The first step of the ligament repair starts with the insertion of a 4.75-mm × 15-mm SwiveLock loaded with a FiberTape and inserted into the intercolicular tunnel of the tibial malleolus.

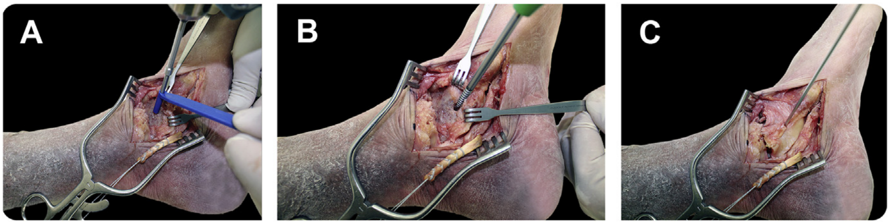

Fig. 13. Talar tunnel preparation. (*A*) Retraction of the deltoid ligament distally and drilling of the talar tunnel with angulation toward the talar body. (*B*) Tapering of the talar tunnel. (*C*) After preparation is completed, the deltoid ligament is retracted proximally and a stab incision is performed immediately over the talar tunnel position.

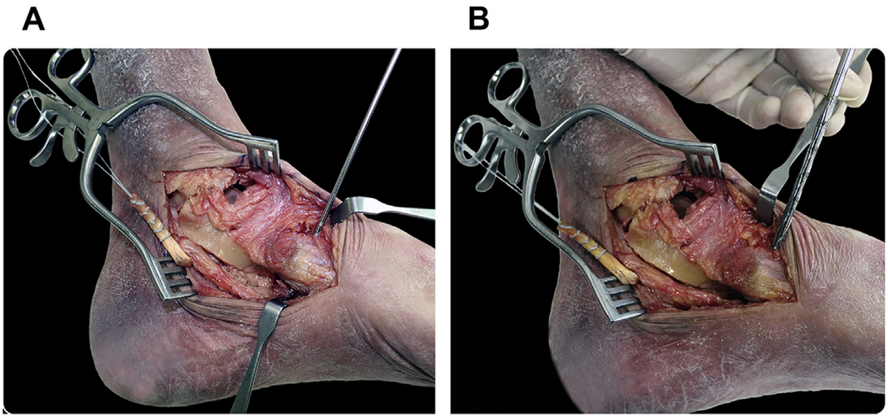

Fig. 14. Navicular tunnel preparation. (*A*) Placing of a K-wire leaving at least 1 cm of bone from the medial border. (*B*) Drilling with a cannulated 5.0-mm drill from dorsal to plantar.

One of the bands of the FiberTape already anchored to the medial malleolus is passed through the 4-mm PEEK Eyelet of a 4.75-mm × 13.5-mm SwiveLock and placed into the talus. Care is taken not to overtighten this augmentation, by placing a clamp underneath the tape and marking the amount of tape that is driven into the tunnel. This step completes the tibiotalar arm of the deltoid ligament augmentation.

Next, the tibiocalcaneal arm of the FiberTape (already anchored to the tibial malleolus) is passed through the 4-mm PEEK Eyelet of a 3.5-mm × 13.5-mm SwiveLock in which another no. 2 FiberTape was mounted. This additional step is used for SLC augmentation. This anchor is placed in the sustentaculum tunnel, taking the same precautions not to overtighten the repair and holding the foot in neutral dorsiflexion and slight external rotation. This step completes the deltoid ligament augmentation (**Fig. 16**).

The final step is the SLC augmentation with the FDL tendon transfer. As the last step of the procedure, both bands of the FiberTape attached to the sustentaculum are passed through the bone tunnel at the navicular bone. One of them is

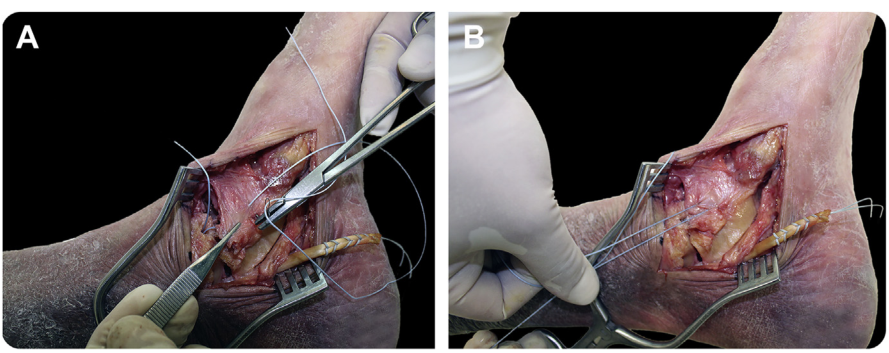

Fig. 15. Medial retightening. (*A*) Mason-Alley stitch using the 3.5 mm anchor previously placed at the medial malleolus. (*B*) Retightening with the foot placed in inversion.

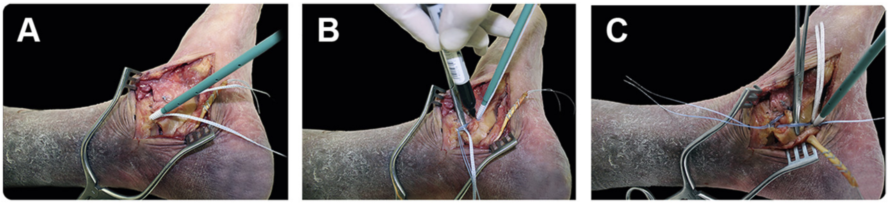

Fig. 16. Deltoid ligament augmentation. (*A*) Insertion of a SwiveLock with a FiberTape at the tibial tunnel. (*B*) One of the bands of the FiberTape already anchored to the tibial malleolus is placed into the talus tunnel. (*C*) The other band is placed on the sustentaculum tunnel with another SwiveLock with a mounted FiberTape for SLC augmentation.

from dorsal to plantar and the other is passed together with the FDL tendon from plantar to dorsal. Both FiberTape bands aim to recreate the native SLC anatomy. Full tension is applied to the tape branches and the FDL tendon, while maintaining the talonavicular joint in a reduced position. Finally, a 4.75-mm SwiveLock is inserted from plantar to dorsal to secure the construct (Fig. 17).

A removable boot is installed for 6 weeks to protect the FDL transfer. At this point, an intensive physiotherapy protocol is initiated to improve inversion strength. In cases of bony procedures that have been undertaken, the authors suggest maintaining the patient non–weight bearing for 3 weeks.

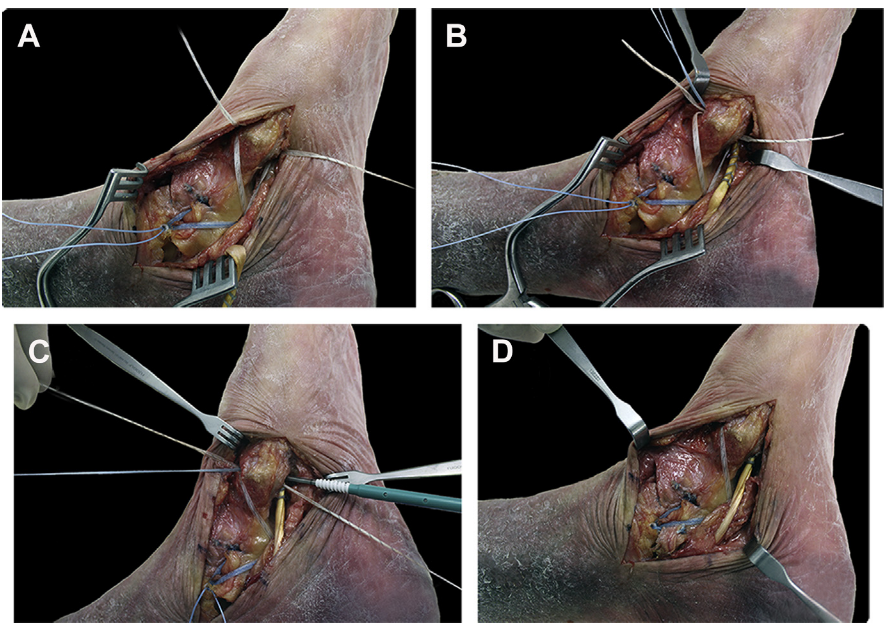

Fig. 17. SLC augmentation with FDL transfer. (*A*) Both bands of the FiberTape attached to the sustentaculum are passed through the navicular tunnel. (*B*) One of the bands is passed dorsal to plantar and the other together with the FDL tendon is passed from plantar to dorsal. (*C*) A 4.75-mm SwiveLock is inserted from plantar to dorsal to secure the whole construct. (*D*) Completed combined deltoid and SLC augmentation with FDL transfer.

SUMMARY

Currently, the biomechanical role of the SLC has been clearly elucidated as the main static restrain of the talonavicular joint. Isolated injury or secondary failure due to PTT dysfunction is responsible for midfoot abduction deformity and loss of the medial arch of the foot.

Even though there is a growing interest among orthopedic surgeons in including SLC repair or reconstruction as part of the flatfoot treatment plan, efficacy of such techniques has been difficult to quantify due to variable approaches and number of concomitant procedures carried out during flatfoot reconstruction.

Nevertheless, there is growing evidence that suggest that SLC reconstruction is capable of providing an excellent correction of the talonavicular deformity and re-establishment of the ligamentous structures of the midfoot arch, whereas bony procedures and tendon transfers alone commonly fail to do so.[5,17,32,34,42]

Myriad techniques for repairing, with and without augmentation or reconstructing the SLC, have been described, but no clinical evidence has shown superiority of any of these approaches. Comparative clinical studies with patient-reported outcomes are necessary to quantify the real effect of this techniques.

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